Cyclonic Separating Apparatus

The invention relates to cyclonic separating apparatus. Cyclonic separating apparatus is known to be used to separate materials from one another, those materials commonly being in different phases (eg, solids from gases, solids from liquids, or liquids from gases), although it is perfectly possible to use such apparatus to separate denser gases or liquids from lighter gases or liquids. Cyclonic separating apparatus is also known to be used to good effect in vacuum cleaners, where solid matter (dirt, dust and debris) is separated from an airflow and retained in the vacuum cleaner prior to disposal whilst the cleaned air is expelled into the atmosphere. The present invention is particularly, although not exclusively, suitable for use in vacuum cleaners.

One of the problems known to be associated with vacuum cleaners is that of noise. It is also perceived that a vacuum cleaner having a higher measure of "airwatts" (which is related to the amount of suction developed by the cleaner at the inlet thereof) will perform better than a vacuum cleaner having a lower measure of airwatts. In relation to the latter, it is well understood that minimising friction losses and pressure drops within the cleaner will result in a maximised measure of airwatts.

The prior art shows that it is known to recover pressure in cyclonic separating apparatus by providing blades or vanes in the outlet thereof such that the spiralling airflow is straightened. See, for example, US 2,771,157. In general, the outlets of cyclonic separating apparatus are normally formed by cylindrical tubes, also known as vortex finders. Outlets which are not cylindrical have occasionally been proposed and US 522,769 illustrates a hexagonal outlet, although no reference is made in the description to the shape of the outlet, nor why the outlet is formed in this way.

It is an object of the invention to provide cyclonic separating apparatus which, when in use, is comparatively quiet. It is another object of the invention to provide cyclonic separating apparatus which, when used in a vacuum cleaner, provides the vacuum cleaner with a comparatively high measure of airwatts.

The invention provides cyclonic separating apparatus for separating solid material from a fluid, the apparatus having a separating chamber, an inlet communicating with the separating chamber for carrying the fluid with the solid matter entrained therein to the separating chamber, and an outlet for carrying the fluid away from the separating chamber after the solid material has been separated therefrom, the outlet being formed by a conduit communicating with the interior of the separating chamber and having a longitudinal axis, wherein a plurality of grooves are formed in an interior surface of the conduit, the grooves extending in the same direction as the longitudinal axis.

The provision of the grooves in the interior surface of the conduit (which forms the vortex finder) has the effect of reducing the amount of noise generated by the apparatus when in use, at least in comparison to cyclonic separating apparatus in which the grooves are not present but is in all other respects identical. Furthermore, the grooves have been found to produce pressure recovery in the airflow passing through the conduit in a manner similar to that produced by the aforementioned vanes shown in the prior art. Advantageously, though, the cost of providing simple longitudinal grooves in the interior surface of the conduit is likely to be considerably lower than the provision of the said vanes.

The reasons why the observed benefits, particularly in relation to noise, are achieved by the provision of the grooves is not fully understood. It is thought possible that the presence of the grooves may interfere with the precession of internal vortices around the conduit as the airflow passes out of the apparatus, thus reducing the amount of noise generated by these vortices. However, it may transpire that other explanations will be discovered at a later date.

Preferably, the grooves extend along at least one quarter of the length of the conduit, more preferably at least half of the length of the conduit and still more preferably substantially the entire length of the conduit. It is preferred that the grooves are all the same shape in cross-section with triangular and rectangular shapes being preferred.

In a preferred embodiment, adjacent grooves are spaced apart from one another by portions of the interior surface of the conduit. Preferably, the portions of the interior surface of the conduit lie on a cylindrical surface. More preferably, the width of each groove is smaller than, or substantially the same as, the width of each portion of the interior surface adjacent the groove.

The optimum number of grooves is believed to be at least eight and more preferably twelve, but a beneficial effect as been observed with as few as four grooves. Further beneficial effects have also been observed when the lowermost end of the conduit is provided with a radiused outer edge.

Embodiments of the invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a schematic side view of cyclonic separating apparatus according to the present invention;

Figure 2 is a perspective view of a vortex finder according to the prior art;

Figure 3 is a perspective view of a vortex finder forming part of the cyclonic separating apparatus of Figure 1;

Figure 4a is a cross-section through the vortex finder of Figure 3 shown on an enlarged scale;

Figure 4b shows a detail of Figure 4a on a further enlarged scale;

Figure 5a is a cross-section through a first alternative vortex finder, similar to that shown in Figure 4a;

Figure 5b is a cross-section through a second alternative vortex finder, similar to that shown in Figure 4a;

Figure 5c is a cross-section through a third alternative vortex finder, similar to that shown in Figure 4a;

Figure 6a is a longitudinal section through the vortex finder shown in Figure 5b;

Figure 6b is a longitudinal cross-section through a fourth alternative vortex finder, similar to that shown in Figure 6a;

Figure 6c is a longitudinal cross-section through a fifth alternative vortex finder, similar to that shown in Figure 6a;

Figure 6d is a longitudinal cross-section through a sixth alternative vortex finder, similar to that shown in Figure 6a;

Figure 7 is a cross-section through a seventh alternative vortex finder, similar to that shown in Figure 4a;

Figure 8 shows a detail of the vortex finder shown in Figure 4a; and

Figures 9a, 9b and 9c illustrate vacuum cleaners in which cyclonic separating apparatus according to the invention may be utilised.

Cyclonic separating apparatus according to the invention is shown schematically in Figure 1. The apparatus 10 generally comprises a cyclone body 12 having an inlet 14 and an outlet or vortex finder 20. The cyclone body 12 is illustrated here as having an upper cylindrical portion 12a and a lower frusto-conical portion 12b which tapers away from the cylindrical portion 12a. The frusto-conical portion 12b terminates in a cone opening 12c which communicates with a collector (not shown). However, it will be

appreciated that cyclone bodies can equally be wholly cylindrical, wholly tapering or even outwardly tapering. Further, the length of the tapering portion in comparison to the cylindrical portion may be varied from that illustrated in Figure 1, as may the angle of taper. The precise shape of the cyclone body 12 is not material to the present invention.

The inlet 14 is here illustrated as lying generally tangentially to the cyclone body 12. However, alternative inlet arrangements can be provided. All that is necessary is that the incoming fluid is caused to move in the cyclone body 12 in a swirling manner by means of which a vortex is formed therein. The tangential inlet 14 could be replaced by a radial or axial inlet together with further means for causing the necessary swirl, such as, for example, helical vanes (not shown). The inlet 14 is formed as a simple pipe and communicates with the interior of the cyclone body 12 at the upper end thereof. The vortex finder 20 is also formed generally as a simple tube and forms a conduit, although further details of the design of the vortex finder 20 will be explained below. The vortex finder 20 is positioned centrally of the cyclone body 12, also at its upper end, ie. at the same end as the inlet 14.

The operation of cyclonic separation apparatus 10 of the type described above is well understood. A fluid having material entrained therein (in the case of vacuum cleaners, this is an airflow having dirt, dust and debris entrained therein) enters the cyclone body 12 via the inlet 14. The arrangement of the inlet 14 is such that the fluid whirls around the interior of the cyclone body 12, thus forming a vortex therein. The matter entrained within the fluid flow is separated from the fluid and falls to the lower end of the cyclone body 12 where it exits the cyclone body 12 via the cone opening 12c and falls into the collector (not shown). If no cone opening or collector is provided, the separated matter may collect inside the cyclone body 12 at the lower end thereof.

Meanwhile, the fluid from which the matter has been separated passes inwardly towards the longitudinal axis 16 of the cyclone body 12 and exits the apparatus 10 via the vortex finder 20. The fluid is still spinning at very high angular velocities as it exits the

apparatus 10 and a significant amount of noise is created as the spinning fluid passes through the vortex finder 20.

For comparison purposes, a known prior art vortex finder 18 is illustrated in Figure 2. The known vortex finder 18 has a hollow cylindrical shape and has smooth outer and inner walls 18a, 18b.

Figures 3, 4a and 4b show the vortex finder 20 of the apparatus shown in Figure 1 in more detail. The vortex finder 20 is generally cylindrical in shape and is preferably moulded from a plastics material to form a conduit. The cylindrical wall 22 has an outer surface 22a and an interior surface 22b. The outer surface 22a is cylindrical. The interior surface 22b has a plurality of grooves 24 formed therein. The grooves 24 are triangular in shape and extend from the interior surface 22b towards the outer surface. In the embodiment shown, twelve grooves 24 are equispaced about the longitudinal axis 26 of the vortex finder 20. Each groove 24 is identical in dimensions to the other grooves 24 and extends along the entire length of the vortex finder 20.

As can be seen from Figure 4b, the breadth b of each groove is greater than the depth d thereof. As can be seen from Figure 4a, each groove 24 is separated and spaced apart from adjacent grooves 24 by a portion of the interior surface 22b. The portions of the interior surface 22b which separate the grooves 24 lie on a cylindrical surface. The breadth b of each groove 24 is substantially the same as the breadth B of the portions of the interior surface 22b on either side thereof.

Figures 5a, 5b and 5c illustrate alternative vortex finders suitable for use in cyclonic separating apparatus according to the invention. The vortex finder 120 illustrated in Figure 5a is very similar to that shown in Figures 3, 4a and 4b except that the grooves 124 are rectangular in cross-section instead of triangular. As before, the depth of each groove 124 is less than the breadth thereof and the breadth of each groove is substantially the same as the breadth of the portions of the interior surface 122b on

either side thereof. As before, twelve grooves 124 are equiangularly spaced about the longitudinal axis 126 of the vortex finder 120.

The vortex finder 220 illustrated in Figure 5b differs from the vortex finder 120 illustrated in Figure 5a only in that eight grooves 224 are provided instead of twelve. The grooves 224 are equiangularly spaced about the axis 226. The breadth of the portions of the interior surface 222b between adjacent grooves is thus greater than the breadth of the grooves 224 themselves. In the embodiment shown in Figure 5c, the number of grooves 324 provided in the interior surface 322b of the vortex finder 320 is reduced to four. The breadth of the portions of the interior surface 322b between adjacent grooves is thus still greater than the breadth of the grooves 324 themselves.

Figure 6a is a longitudinal cross-section though the vortex finder 220 shown in Figure 5b. As can be seen, the grooves 224 extend parallel to the axis 226 of the vortex finder 220 along the entire length thereof. Figure 6b illustrates a further alternative embodiment of the present invention in which the grooves 424 extend along the vortex finder 420 to a distance L1 which is approximately half of the length L of the vortex finder 420. Figure 6c illustrates yet another embodiment of the present invention in which the grooves 524 extend along the vortex finder 520 to a distance L2 which is approximately one quarter of the length L of the vortex finder 520. In each case, the grooves 424, 524 are located in the upstream end of the respective vortex finder 420, 520.

Figure 6d illustrates a modification to the vortex finder 220 shown in Figures 5b and 6a in which the upstream end of the vortex finder 220 has a radius r applied to the outer surface 222a. This modification can be applied to any of the previously described embodiments. The radius r is sufficiently large to ensure that the outermost extremity of each groove 224 terminates in a different plane to the innermost extremity of the groove 224.

Figure 7 shows a further alternative vortex finder 620 which is similar to that shown in Figures 3, 4a and 4b. The vortex finder 620 differs from that shown in the previous drawings in that the grooves 624 are larger than the grooves 24. This has the effect of reducing the breadth of the portions of the interior surface 622b between the grooves 624 so that the breadth of the portions of the interior surface 622b between the grooves 624 is smaller than that of the grooves 624 themselves. Experiments show that reducing the breadth of the portions of the interior surface 622b to less than that of the grooves 624 improves the performance of the cyclonic separating apparatus at least in relation to noise reduction.

It has also been found that the amount of noise reduction achievable is increased if a small ridge or protrusion is formed along at least one edge of the groove 24. Figure 8 illustrates two alternative protrusions 25a, 25b, one being illustrated on each side of the groove 24. The protrusion 25a, located in Figure 8 to the right of the groove 24, is generally triangular in shape, having stright sides and a sharp apex. The protrusion 25b, located to the left in Figure 8, is generally rounded in profile. Each protrusion 25a, 25b extends outwardly from the interior surface 22b towards the axis 26 and along the length of the groove 24. It is envisaged that the protrusions may however extend only part way along the groove 24 and that only one protrusion 25a, 25b may be provided adjacent each groove 24. Furthermore, it is possible that a similar noise-reducing effect may be achievable by providing protrusions 25a, 25b adjacent only some of the grooves 24 provided in the interior surface 22b of the vortex finder 20.

Figures 9a, 9b and 9c illustrate three different types of vacuum cleaner in which cyclonic separating apparatus according to the invention can advantageously be utilised. The cylinder vacuum cleaner shown in Figure 8a incorporates two single cyclones 32, 34 arranged in series, one of which is located inside the other. It is envisaged that the invention would be utilised to its best advantage in relation to the interior cyclone 34. Figures 8b and 8c illustrate cylinder and upright vacuum cleaners respectively in each of which a single upstream cyclone 36 is followed by a plurality of downstream

cyclones 38 arranged in parallel. The invention is expected to be of the greatest benefit when used in relation to some or all of the downstream cyclones 38.

It has been found that, by replacing the traditional, cylindrical vortex finder with a vortex finder having longitudinal grooves extending along at least part of its length, the noise generated by the cyclonic separating apparatus, at least when used in a vacuum cleaner, is reduced. Furthermore, the grooves appear to be able to achieve a significant amount of pressure recovery in the airflow as it exits the cyclonic separating apparatus. This has significant benefits to the consumer in that the airwatts achievable by the vacuum cleaner is increased, which in turn has a beneficial effect on the pickup performance of the cleaner.

The invention is not intended to be limited to the precise details of the embodiments shown in the accompanying drawings. Variations and modifications will be apparent to a skilled reader. For example, the grooves need not be precisely equiangularly spaced about the longitudinal axis of the vortex finder. The number of grooves provided could be varied and their shape could also be other than rectangular or triangular.